TCP/IP

Transmission Control Protocol / Internet Protocol

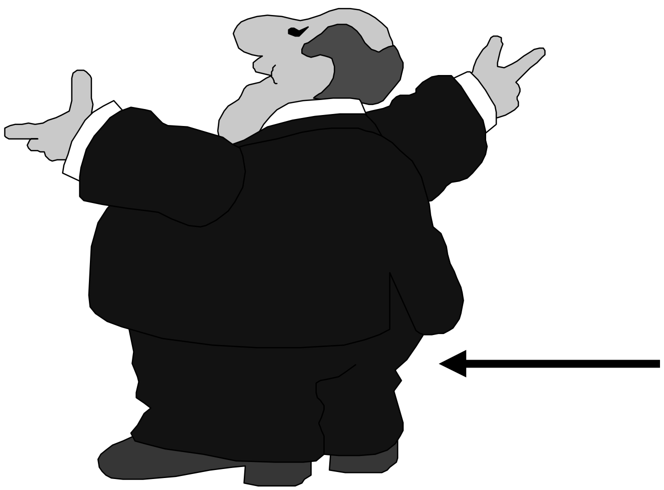
1

TCP/IP & OSI

- In OSI reference model terminology -the TCP/IP protocol suite covers the network and transport layers.
- TCP/IP can be used on many data-link layers (can support many network hardware implementations).

2

But First ...



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Ethernet - A Real Data-Link Layer

- It will be useful to discuss a real data-link layer.
- Ethernet (really IEEE 802.3) is widely used.
- Supported by a variety of physical layer implementations.

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Ethernet

- Multi-access (shared medium).
- Every Ethernet interface has a unique 48 bit address (a.k.a. *hardware address*).
- Example: `C0:B3:44:17:21:17`
- The broadcast address is all 1's.
- Addresses are assigned to vendors by a central authority.

CSMA/CD

Carrier Sense Multiple Access
with
Collision Detection

- *Carrier Sense*: can tell when another host is transmitting
- *Multiple Access*: many hosts on 1 wire
- *Collision Detection*: can tell when another host transmits at the same time.

An Ethernet Frame

Preamble	Destination Address	Source Address	Length	DATA	CRC
8 bytes	6	6	2	0-1500	4

- The preamble is a sequence of alternating 1s and 0s used for synchronization.
- CRC is Cyclic Redundency Check

Ethernet Addressing

- Each interface looks at every *frame* and inspects the destination address. If the address does not match the hardware address of the interface or the broadcast address, the frame is discarded.
- Some interfaces can also be programmed to recognize multicast addresses.

Back to TCP/IP

Internet Protocol
The IP in TCP/IP

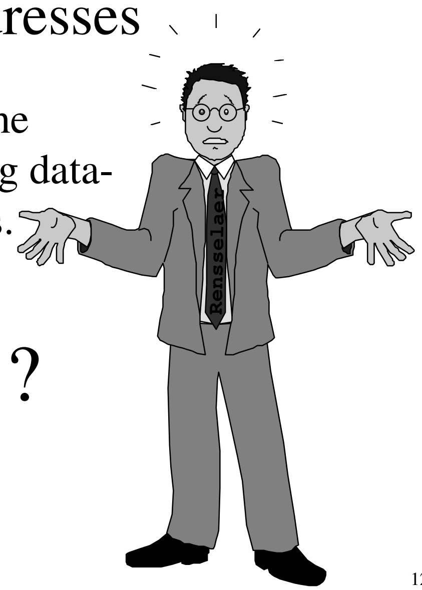
- IP is the network layer
  - packet delivery service (host-to-host).
  - translation between different data-link protocols.

IP Datagrams

- IP provides connectionless, unreliable delivery of *IP datagrams.*
- *Connectionless*: each datagram is independent of all others.
- *Unreliable:* there is no guarantee that datagrams are delivered correctly or at all.

IP Addresses

- IP addresses are not the same as the underlying data-link (MAC) addresses.



Why ?

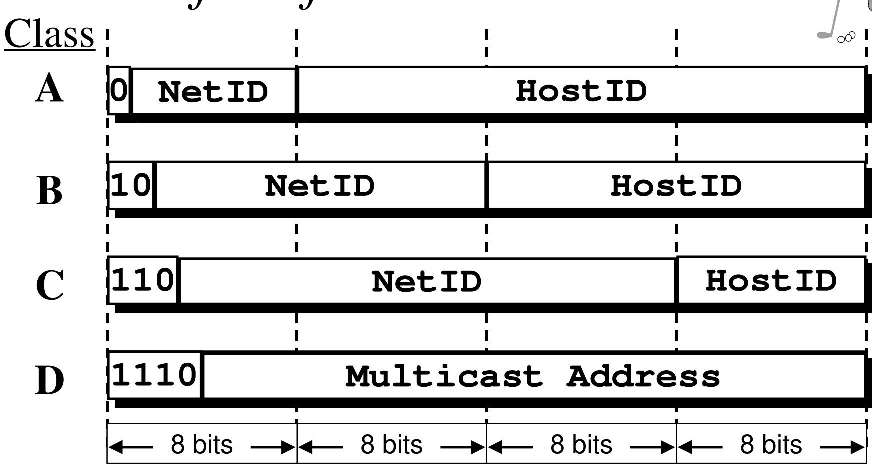
IP Addresses

- IP is a network layer - it must be capable of providing communication between hosts on different kinds of networks (different data-link implementations).
- The address must include information about what *network* the receiving host is on. This makes routing feasible.

IP Addresses

- IP addresses are *logical* addresses (not physical)
- 32 bits.
- Includes a network ID and a host ID.
- Every host must have a unique IP address.
- IP addresses are assigned by a central authority (the NIC at SRI International).

The *four for*mats of IP Addresses



<u>Class A</u>

- 128 possible network IDs
- over 4 million host IDs per network ID

<u>Class B</u>

- 16K possible network IDs
- 64K host IDs per network ID

<u>Class C</u>

- over 2 million possible network IDs
- about 256 host IDs per network ID

Network and Host IDs

- A Network ID is assigned to an organization by a global authority.
- Host IDs are assigned locally by a system administrator.
- Both the Network ID and the Host ID are used for routing.

IP Addresses

- IP Addresses are usually shown in *dotted decimal* notation:

1.2.3.4 → `00000001 00000010 00000011 00000100`

- cs.rpi.edu is 128.213.1.1

`10000000 11010101 00000001 00000001`

CS has a class B network

Host and Network Addresses

- A single network interface is assigned a single IP address called the *host* address.
- A host may have multiple interfaces, and therefore multiple *host* addresses.
- Hosts that share a network all have the same IP *network* address (the network ID).

IP Broadcast and Network Addresses

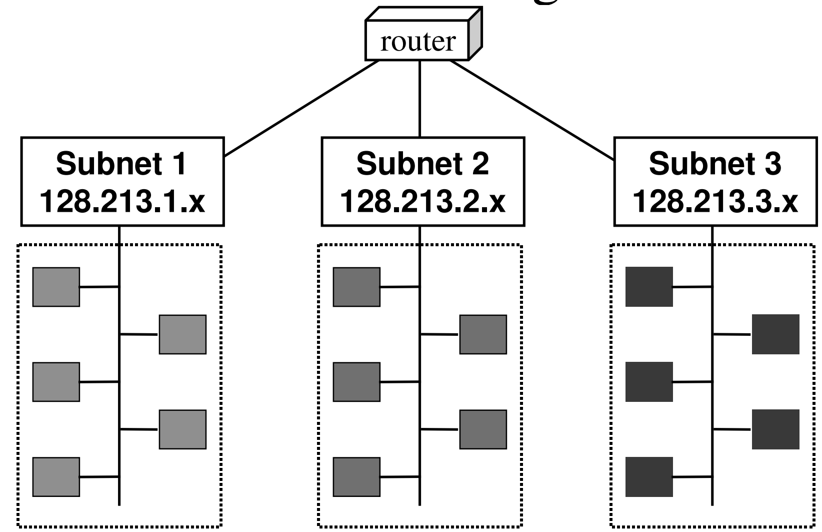
- An IP broadcast addresses has a host ID of all 1s.
- IP broadcasting is not necessarily a true broadcast, it relies on the underlying hardware technology.
- An IP address that has a host ID of all 0s is called a *network address* and refers to an entire network.

Subnet Addresses

- An organization can subdivide it's host address space into groups called subnets.
- The subnet ID is generally used to group hosts based on the physical network topology.

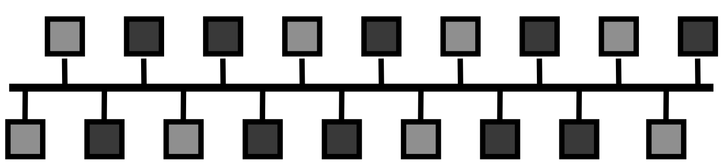
10	NetID	SubnetID	HostID

Subnetting



Subnetting

- Subnets can simplify routing.
- IP subnet broadcasts have a hostID of all 1s.
- It is possible to have a single wire network with multiple subnets.



Mapping IP Addresses to Hardware Addresses

- IP Addresses are not recognized by hardware.
- If we know the IP address of a host, how do we find out the hardware address ?
- The process of finding the hardware address of a host given the IP address is called

Address Resolution

Reverse Address Resolution

- The process of finding out the IP address of a host given a hardware address is called

  Reverse Address Resolution

- Reverse address resolution is needed by diskless workstations when booting.

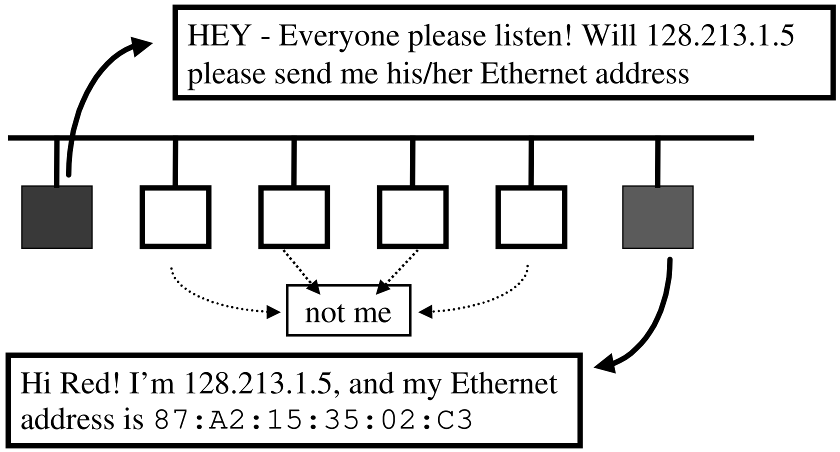
ARP

- The *Address Resolution Protocol* is used by a sending host when it knows the IP address of the destination but needs the Ethernet address.
- ARP is a broadcast protocol - every host on the network receives the request.
- Each host checks the request against it's IP address - the right one responds.

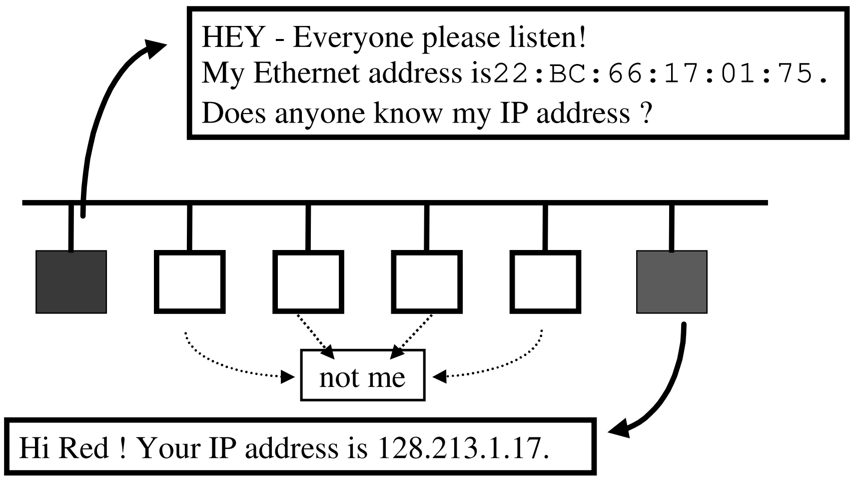
ARP

- ARP does not need to be done every time an IP datagram is sent - hosts *remember* the hardware addresses of each other.
- Part of the ARP protocol specifies that the receiving host should also remember the IP and hardware addresses of the sending host.

ARP



RARP



Services provided by IP

- Connectionless Delivery (each datagram is treated individually).
- Unreliable (delivery is not guaranteed).
- Fragmentation / Reassembly (based on hardware MTU).
- Routing.
- Error detection.

IP Datagram

1 byte		1 byte	1 byte		1 byte
VERS	HL	Service	Fragment Length		
Datagram ID			FLAG	Fragment Offset	
TTL		Protocol	Header Checksum		
Source Address					
Destination Address					
Options (if any)					
Data					

IP Datagram Fragmentation

- Each fragment (packet) has the same structure as the IP datagram.
- IP specifies that datagram reassembly is done only at the destination (not on a hop-by-hop basis).
- If any of the fragments are lost - the entire datagram is discarded (and an ICMP message is sent to the sender).

IP Datagram Fragmentation

- If packets arrive too fast - the receiver discards excessive packets and sends an ICMP message to the sender (SOURCE QUENCH).
- If an error is found (header checksum problem) the packet is discarded and an ICMP message is sent to the sender.

ICMP
Internet Control Message Protocol

- ICMP is a protocol used for exchanging control messages.
- ICMP uses IP to deliver messages.
- ICMP messages are usually generated and processed by the IP software, not the user process.

ICMP Message Types

- Echo Request
- Echo Response
- Destination Unreachable
- Redirect
- Time Exceeded
- Redirect (route change)
- there are more ...

IP/BYE-BYE

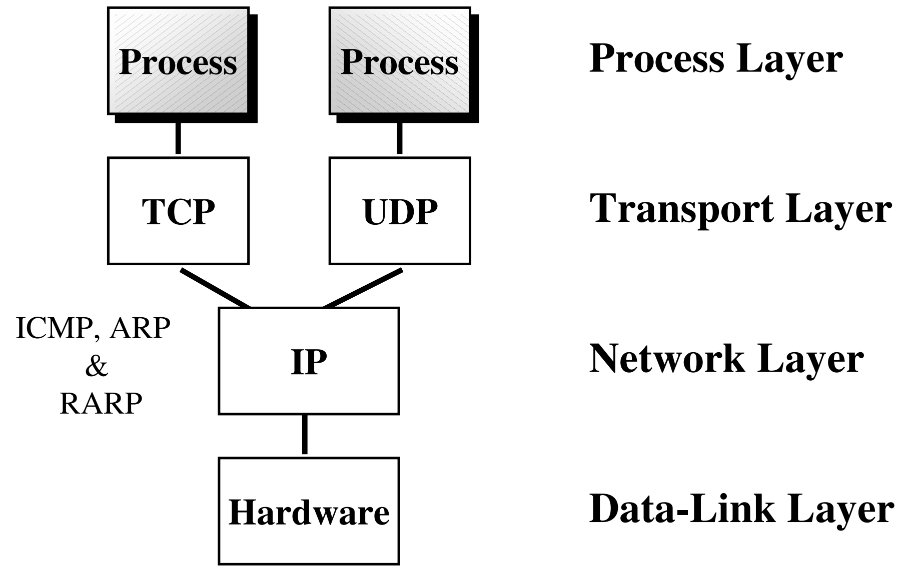
- IP/BYE-BYE is a lecture protocol used to signal the class that we have just finished our discussion of IP - the network layer of TCP/IP.
- The appropriate response to an IP/BYE-BYE request is immediate applause, although simply opening your eyes is enough (known as a WAKEUP response).

Transport Layer & TCP/IP

Q: We know that IP is the network layer - so TCP must be the transport layer, right ?

A: No.

TCP is only part of the TCP/IP transport layer - the other part is UDP (User Datagram Protocol).



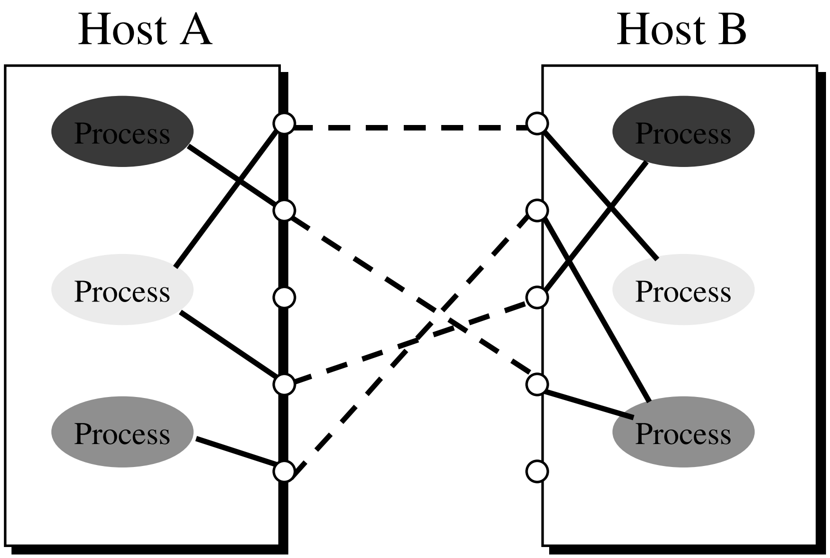
UDP

- UDP is a transport protocol
  - communication between <u>processes</u>
- UDP uses IP to deliver datagrams to the right host.
- UDP uses *ports* to provide communication services to individual processes.

Ports

- TCP/IP uses an abstract destination point called a protocol port.
- Ports are identified by a positive integer.
- Operating systems provide some mechanism that processes use to specify a port.

Ports



UDP

- Datagram Delivery
- Connectionless
- Unreliable
- Minimal

UDP Datagram Format

Source Port	Destination Port
Length	Checksum
Data	

TCP
Transmission Control Protocol

- TCP is an alternative transport layer protocol supported by IP.
  - TCP provides:
    - Connection-oriented
    - Reliable
    - Full-duplex
    - Byte-Stream

Connection-Oriented

- *Connection oriented* means that a virtual connection is established before any user data is transferred.
- If the connection cannot be established - the user program is notified.
- If the connection is ever interrupted - the user program(s) is notified.

Reliable

- *Reliable* means that every transmission of data is acknowledged by the receiver.
- If the sender does not receive acknowledgement within a specified amount of time, the sender retransmits the data.

Byte Stream

- *Stream* means that the connection is treated as a stream of bytes.
- The user application does not need to package data in individual datagrams (as with UDP).

Buffering

- TCP is responsible for buffering data and determining when it is time to send a datagram.
- It is possible for an application to tell TCP to send the data it has buffered without waiting for a buffer to fill up.

Full Duplex

- TCP provides transfer in both directions.
- To the application program these appear as 2 unrelated data streams, although TCP can piggyback control and data communication by providing control information (such as an ACK) along with user data.

TCP Ports

- Interprocess communication via TCP is achieved with the use of ports (just like UDP).
- UDP ports have no relation to TCP ports (different name spaces).

TCP Segments

- The chunk of data that TCP asks IP to deliver is called a *TCP segment*.
- Each segment contains:
  - data bytes from the byte stream
  - control information that identifies the data bytes

TCP Segment Format

1 byte	1 byte	1 byte	1 byte
Source Port		**Destination Port**	
Sequence Number			
Request Number			
offset **Reser.**	**Control**	**Window**	
Checksum		**Urgent Pointer**	
Options (if any)			
Data			

Addressing in TCP/IP

- Each TCP/IP address includes:
  - Internet Address
  - Protocol (UDP or TCP)
  - Port Number

TCP vs. UDP

Q: Which protocol is better ?

A: It depends on the application.

TCP provides a connection-oriented, reliable byte stream service (lots of overhead).

UDP offers minimal datagram delivery service (as little overhead as possible).

TCP/IP Summary

- IP: network layer protocol
  - unreliable datagram delivery between hosts.
- UDP: transport layer protocol
  - unreliable datagram delivery between processes.
- TCP: transport layer protocol
  - reliable, byte-stream delivery between processes.

Hmmmmm.
TCP or UDP ?

- Internet commerce ?
- Video server?
- File transfer?
- Email ?
- Chat groups?
- Robotic surgery controlled remotely over a network?